METHOD FOR MAINTAINING AND/OR QUALITATIVELY IMPROVING A COMMUNICATION PATH IN A RELAY SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

The present application is a continuation of international application PCT/DE02/03162, filed 28 August, 2002, and which designates the U.S. The disclosure of the referenced application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates to a method for maintaining and/or qualitatively improving a communication path in a relay system, such as a radio network, wherein information is transmissible between two devices via one or more additional devices along the thus-formed communication path.

Within the scope of the present invention a relay system or communication system is understood to be a system which permits devices to transmit information directly to other devices, i.e., without the use of further devices. Whether or not two devices are able to communicate with each other directly, may depend on factors which vary in the course of time, for example, because the devices move, or the transmission paths and/or transmission characteristics change.

Within the scope of the present invention, a relay system is understood to be a communication system in the above meaning, which permits exchanging information between a device A_0 and a device $A_0(n>1)$, via a series of devices $A_1, \dots$ to A_{n-1}, which function as intercarriers. In this process, the device A_i directly communicates with the device A_{i+1} by means of a transmission technology TT_{i+1} $(i=0, \dots, n-1)$. This connection between A_0 and A_n via the series of devices A_0, A_1, …, A_{n-1}, A_n

by means of the transmission technologies TT_{i+1} ($i=0, \ldots, n-1$) is called communication path, and expressed as

$$A_0 - TT_1 - A_1 - TT_2 - A_2 \ldots A_{n-2} - TT_{n-1} - A_{n-1} - TT_n - A_n.$$

The direct connection by means of the transmission technology TT_{i+1} between two devices A_i and A_{i+1} ($0<i<n$) is called a link and expressed as

$$A_i - TT_{i+1} - A_{i+1}.$$

Devices of the relay system, which are capable of functioning as intercarriers are called relays. An end device may simultaneously be a relay. A part of the communication path between relay A_k and A_l ($0<k<l<n$) via the series of devices A_k, A_{k+1}, ..., A_{l-1}, A_l by means of the transmission technologies TT_{i+1} ($i=k, \ldots, l$) is called leg and expressed as

$$A_k - TT_{k+1} - A_{k+1} - TT_{k+2} - A_{k+2} \ldots A_{l-2} - TT_{l-1} - A_{l-1} - TT_l - A_l.$$

In a relay system, devices are thus able to communicate with one another via paths. Unlike other communication networks, for example, the currently known cellular mobile radio networks, such as, for example, GSM, UMTS, PDC, CDMA2000, IS95, a relay system permits all relays performing the same relay functions within the scope of their physical capabilities. In this meaning, examples for relay systems are radio relay systems, the Internet, Intranets, and Local Area Networks.

In a relay system, the connection quality via a communication path is subjected to time variations. In this connection, there exists a dependency, among other

things, on the transmission quality of the individual links and on the load situations in the relay system. The quality of the relay system is largely defined by the possibility of being able to select communication paths of a better quality of service (QoS). Known methods of the art provide this in a way that is not satisfactory for relay systems.

It is therefore an object of the present invention to provide a method for maintaining and/or qualitatively improving a communication path in a relay system, which permits maintaining the link quality at a high level, even when transmission conditions vary in the course of time.

SUMMARY OF THE INVENTION

In accordance with the invention, the foregoing object is accomplished by a method wherein at least one leg of the communication path can be replaced with a substitution path as a function of at least one predeterminable parameter, or be used at least at times simultaneously with a substitution path.

In a method according to the invention, it has been found with respect to one aspect of the invention that the exchange of at least one leg of the communication path for a more suitable leg, accomplishes the foregoing object in a surprisingly simple manner. Such an exchange or substitution step could occur as a function of at least one predeterminable parameter. As an alternative, the at least one leg of the path could be usable at least at times simultaneously with a more suitable leg of the path, namely the substitution path. Likewise, this at least temporarily simultaneous use could occur as a function of at least one predeterminable parameter. As

a parameter, it would be possible to use a predeterminable quality threshold value.

A limitation concerning the legs of the communication path that are to be substituted is absent. A substitution or simultaneous use is possible in any point and along any desired number of links of the communication path. In most cases, it is not necessary to substitute the communication path as a whole.

Consequently, the method of the invention indicates a method, which permits maintaining the link quality at a high level, even in the case of transmission conditions that vary in the course of time.

As regards a reliable implementation of the method according to the invention, one could assign a connection identifier to the connection that is defined or produced between the two devices. This identifier could be unambiguous as long as there are devices, for which the connection is found existing. The connection identifier could consist of an identifier of the one device A_0 in the relay system, which is unambiguous at a predeterminable time, and of a temporary identifier, preferably selected by A_0. After the path for A_0 no longer exists, A_0 will not newly assign this temporary identifier during a period, which is adequately long, so that the devices of the system consider the path no longer existing.

Furthermore, with respect to a reliable implementation of the method, it would be possible to communicate to A_0 and/or the end device A_n, each change of a path of the devices, relays and/or end devices, that are involved in the path change. Furthermore, one could assign to the path a path identifier that is

unambiguous at a given time and, preferably, takes into account each path change.

Furthermore, with respect to a reliable method, one could assign to at least one device A_i ($i=0, \dots n$) in the path a device identifier for each exchange of information via the path. In a particularly simple manner, this device identifier could consist of the path identifier and the position i in the path.

Depending on need, it would be possible to assign the connection identifier, and/or the temporary identifier, and/or the path identifier, and/or the device identifier by one or both of the two devices A_0 and/or A_n, which are each arranged at the ends of the communication path.

In the relay system, a relay that can directly communicate with a device A_i, is called an adjacent relay of A_i. A relay adjoining an adjacent relay of A_i is called an adjacent relay of the second order of A_i. In general, for an integer $n>0$, a relay adjoining an adjacent relay of the nth order of A_i is called an adjacent relay of the $(n+1)$th order of A_i.

To ensure a reliable sequence of the process, one could provide in the relay system that each device exchanges data with its adjacent relay. These data could comprise in particular the identifications of existing connections and/or paths, connection identifiers and/or path identifiers, and/or the position i in the path of neighbors of a predeterminable order. In a particularly reliable manner, the exchange of data could occur periodically. A device A_i pertaining to an existing path could use these data to develop or generate substitute paths.

Concretely, a device A_i will be able to designate an adjacent relay D of the first order a substitution

candidate, when the adjacent relay D has been for a predeterminable time the adjacent relay of the first order of A_i and belongs to the same connection and/or the same path, but is neither A_{i-1} nor A_{i+1}. To this, one could add as an additional facultative condition that a link quality between the device A_i and the adjacent relay D include or exceed a predeterminable quality.

In this connection, it is only necessary to exchange the identifications of existing connections or paths of neighbors up to the first order. As an alternative, each device participating in the path could transmit via the path at least one of its identities or identifiers to all other devices of the path or to the nearest K devices, if present, in both directions of the path. As an alternative or in addition, each device could transmit the same identity to its neighbors of the first or a predeterminable higher order. The identity or identifier could be device-specific and/or subscriber-specific. Preferably, the value K could be predeterminable by the relay system. Furthermore, the value K could be at least temporarily reducible preferably by a device, when a signaling load exceeds a predeterminable value.

In an alternative sequence of the process for determining a substitution candidate, one could use in particular a relay that belongs to a path for transmitting the path identifier P and the position i to its adjacent relays of the first order. Furthermore, information could be communicated in the relay system via a device in the path to as far as lth neighbors of devices of the path, so that a device that is an mth neighbor of a device in the path ($m \leq 1$) knows

at least one neighbor of the (m-1)th order of the device in the path.

A device A_i, which occupies in a loopfree path with the path identifier P the position i will then be able to designate an adjacent relay D a substitution candidate, when a relay occupying in the path with the path identifier P the position k in the path is known to this adjacent relay D as adjacent relay of the 1th order, and when the adjacent relay D is for a predeterminable time an adjacent relay of the first order of A_i, and when preferably a link quality between the device A_i and the adjacent relay D has or exceeds a predeterminable quality.

A further process of detecting a substitution candidate could proceed as follows:

Each device of the path initially communicates to the other devices of the path one of its identities and/or identifiers by signaling on the path. The identities and/or identifiers could be subscriber-specific and/or device-specific. In the above-described exchange of information with adjacent devices, the same identity is periodically transmitted instead of the path identifier and position in the path. With that, a device A_i of a path

$$A_0 - TT_1 - A_1 - TT_2 - A_2 \ldots A_{n-2} - TT_{n-1} - A_{n-1} - TT_n - A_n$$

is able to detect that besides A_{i+1} and A_{i-1} -- or besides A_{i+1}, when i=0, or besides A_{1-1}, when i=n -- an additional relay of the same path is a neighbor of the nth order.

A further process for detecting a substitution candidate could proceed as follows:

To begin with, devices or relays could exchange with their adjacent relays of the first order adjacency information about their adjacent relays of the lth order. The adjacency information could comprise the identity and the order of the adjacency. On existing paths, each device participating in the path could transmit via the path the adjacency information to all other devices of the path or to the nearest K devices, if present, in both directions of the path.

It will be possible to designate an adjacent relay of the first order a substitution candidate, when the adjacent relay is simultaneously known to a relay that occupies in the path with the path identifier P the position k, as adjacent relay of an order that is ≤l.

The aforesaid values l and/or K could preferably be predeterminable by the system. If a signaling load exceeds a predeterminable value, the values l and/or K could be reducible at least temporarily. The reduction could be performed by a predeterminable device.

Before a substitution step in accordance with the invention, it would be possible to perform an examination proceeding, which would determine whether a substitution step has to occur. More specifically, to examine whether a link between two devices or relays is disturbed or interrupted, or assumed to be disturbed or interrupted, one could perform in a very simple manner a link diagnosis and/or link signaling.

Concretely, when proceeding from a transmission technology TT_{i+1} that is used between the device A_1 and the device A_{i+1}, this transmission technology could typically make available a link diagnosis and/or information for a link diagnosis, which are capable of indicating or permitting the conclusion that a link is disturbed or interrupted, or assumed to be disturbed or

interrupted. For example, the link diagnosis could permit information about the transmission power, receiving power, signal strength of the received signal, and/or their variation. When the relay system provides a link signaling in each link of a path, this link signaling may be used for diagnosing a disturbance or interruption of the link. More specifically a link disturbance is present, when the bit error rate or frame error rate of the link signaling or a combination of both is too high. A link interruption, however, is present, when the link signaling is interrupted.

Such a test could also be used for rating the quality and/or quality of service of the path or leg thereof. More specifically, this could occur, when it is known, when errorfree frames are transmitted from one end of the path or leg of the path by evaluating the bit error rate, the frame error rate, or the throughput, or a combination thereof.

It is likewise possible to rate the quality of service of the path or a leg of the path for an application, when parameters exceed or fall below certain threshold values, which are regulated by regulating mechanisms that are controlled by the application. Examples of such parameters are window sizes, values of timers, or counters.

Concretely, a device A_i could perform a local substitution of a leg of the path, or enable a simultaneous usability of a substitution path, when the link to A_l(j = i-1 or i+1) is interrupted or too greatly disturbed, and/or threatens to be interrupted or too greatly disturbed, and when A_i identifies one or more substitution candidates. Such a situation could be diagnosed by A_i, which could cause A_i to decide on performing the substitution process either by a local

substitution or by the simultaneous utilization of a substitution path. Such a local substitution could also be called a local handover. The substitution process will not occur, only when A_i omits this because of a method that is applied for preventing overlapping substitution processes.

As an alternative thereto, a device A_i could perform a local substitution of a leg or enable a simultaneous usability of a substitution path, when, according to information known to A_i, it is possible to replace an existing leg of the path originating at A_i with a new leg of a shorter length that passes through a substitution candidate R. To this end, a device A_i in a loopfree path could consider as substitution candidate an adjacent relay R that is not in the path. In this connection, A_i could decide whether a substitution process is to be performed. The substitution process will not be performed, only when A_i omits this because of a method that is applied for preventing overlapping substitution processes.

Basically, a local substitution could be initiated in a very simple manner by requesting the substitution candidate to continue to establish the new leg of the path. Based on the information available to it, the substitution candidate could address the nearest relay of the path being formed, and this operation could continue stepwise via additional relays. As a result of forwarding the request from the substitution candidate to further, suitable relays, it would be possible to form a new leg of the path to A_j.

In a further alternative, a device A_1 (i=0 or n) could perform a global substitution, if the quality of the path from A_i to A_j (j=0, or j=n; j≠i) or A_{i-1} (i>0) falls below a predeterminable quality. In this case, A_i

could decide after a corresponding diagnosis by A_i, to perform a global substitution or a so-called global handover. The substitution process will not be performed, only when A_1 omits this because of a method that is applied for preventing overlapping substitution processes.

When a device A_1 starts to perform a local substitution to A_j, it knows at least one substitution candidate as well as the length of the potentially new legs that are to be formed by the at least one substitution candidate. Typically, the device A_i also knows a rating of the -- possibly potential -- link to at least one substitution candidate, which is performed by the respective transmission technology or because of data of the respective transmission technology. A_i will then select a substitution candidate, while suitably taking account of this information. It will establish a link to this candidate, and transmit the request to further establish the new leg of the path.

When A_0 starts to perform a global substitution, A_0 will establish a connection to A_n according to a proceeding that is predetermined in the relay system. The substitution candidate could perform a global substitution by establishing a path between A_0 and A_n according to a nondeterministic method of establishing a path and/or a method that takes into account the network status or the status of the relay system, so that in all likelihood the substitution path differs from the original path. When the device A_n starts to perform a global substitution to A_0 it will proceed in an analogous manner.

In a further analogous manner, the substitution candidate could perform a global substitution by establishing a path between A_i and A_j according to a

nondeterministic method of establishing a path and/or a method that takes into account the network status or status of the relay system, so that in all likelihood the substitution path differs from the original path.

Within the scope of a particularly simple substitution process, it would be possible to begin in the case of a local or global substitution with the establishment of a signaling connection. Once this connection is established, and the quality is adequately satisfactory, it would be possible to switch the service connection from the previous path to the modified or new path. This process will not be possible, when the previous or original path is interrupted. In this case, the service connection will be switched as early as possible to the modified or new substitution path.

With regard to a reliable transmission of information, a service connection could use in the case of a global substitution, both or several paths -- the original and the new path or the new paths -- until the original or one of the new paths has exceeded a quality threshold value. It would then be possible to use only the path of the best quality. Subsequently, i.e., after exceeding the quality threshold value, it would be possible to disconnect less suited paths.

While in the last-described process both or several paths are used, it would be possible to prefer the better-transmitted information, or to combine the information. To this end, a transmission could be performed in packets that are sequenced by identification.

In particular, when changing delays that exceed a predetermined maximum fluctuation are not acceptable in the transmission of user information, whereas a

predetermined maximum delay is acceptable, it will be possible to buffer at the respective destination the user information that is to be transmitted, so that when connecting a new, shorter path, the predetermined maximum fluctuation of the delay is not exceeded. This represents a particularly reliable transmission method.

In practice, two or more participating relays or devices often find within the same period that a substitution process is required. To avoid that two or more devices initiate a substitution process, and that therefore resources are needlessly used, or that even blockings occur, it would be possible to prioritize relays. In so doing, it would be possible to determine already during the path establishment or during a communication, which relay or relays is or are authorized to perform a substitution. As an alternative or in addition, it would be possible to use the knowledge of the own location as well as the location of neighbors in the connection for assigning a distribution of tasks. Thus, it would be possible to authorize the device or relay nearest to a source or destination to perform a substitution. In this connection, it is also of advantage that in the case of interruptions of several adjacent links, it is always possible to allocate in a unambiguous manner the node, or device, or relay that initiates a substitution.

The position in a connection chain can be derived from the hop count or from observing the flow of data or the establishment of the path.

Within the scope of the substitution process, it is useful to disconnect legs of the path that are no longer needed. With respect to such a disconnection of no longer needed paths or legs thereof, it would be possible to compare packets for determining the

direction, in which the newly detected relay or substitution candidate is located. As an alternative or in addition, one could use a test packet for determining the direction. As a further alternative or in addition thereto, the position of the substitution candidate in the path could be communicated to the device A_i.

With respect to a substitution adapted to the respective case of application, it would be possible to perform a substitution as a function of the application. Thus, it is possible to perform for one or more applications using one path, a substitution to a new path or a substitution with two or more simultaneously usable paths.

As regards a particularly individual adaptation of the communication path to existing requirements, it would be possible to use different transmission technologies between the individual devices or relays. The applied transmission technologies may use, for example, a radio transmission, a line-connected transmission, a light wave transmission, an acoustic transmission, or other types of transmission.

Basically, it should be remarked at this point that in the foregoing specification, the expression substitution process stands for both replacing a path or a leg thereof with a substitution path and simultaneously utilizing at least temporarily an original path or a leg thereof and a substitution path or a plurality of substitution paths. In this connection, the expression substitution process comprises both the local and the global substitution or a local and a global handover.

At this point, it should also be pointed out that the parameters i, k, K, l, m, and n as used in this

specification stand for positive natural numbers including zero.

There exist various possibilities of improving and further developing the teaching of the present invention in an advantageous manner. To this end, one may refer to the following description of a preferred embodiment of the invention with reference to the drawing. In conjunction with the description of the preferred embodiment of the invention with reference to the drawing, also generally preferred improvements and further developments of the invention are described in detail.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawing:

Figure 1 is a diagram of a typical establishment of a communication path in a relay system;

Figure 2 is a diagram of a communication path, which comprises six devices; and

Figure 3 is a diagram of a communication path with a parallel-illustrated substitution path.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates a diagram of a typical communication path comprising devices of a relay system. The communication path starts with a device A_0 and ends with a device A_n. TT_1 and TT_n further indicate the transmission technologies used between the devices. These transmission technologies may differ from link to link between the devices.

Likewise, Figure 2 shows a diagram of a communication path, which extends from a device A_0 to a device A_5. Between the devices, the transmission technologies TT_1 to TT_5 are used. The expression "leg"

denotes a segment of the communication path between the device A_1 and the device A_3. A "link" indicates a direct connection between two devices that are adjacent in the communication path, in the Figure A_2 and A_3.

Figure 3 shows a diagram of a communication path from a device A to a device F. Also shown is a simultaneously usable substitution path, which likewise extends from the device A to the device F. However, the connection passes through two additional devices G and H. The original communication path thus extends via the devices A, B, C, D, E, and F, and the substitution path via the devices A, B, G, H, E, and F. Between the individual devices, the transmission technologies are indicated at TT and TT' respectively. The path configuration shown in Figure 3 avoids a loop.

In the configuration shown in Figure 3, it is of special importance that both the original communication path and the substitution path comprise a comparable direct connection respectively between the devices A and B as well as E and F. Only between the devices B and E do the paths pass through different devices, namely on the one hand through devices C and D, and on the other hand through devices G and H.

As regards further advantageous improvements and further developments of the invention, the general part of the specification on the one hand and the attached claims on the other hand are herewith incorporated by reference for avoiding repetitions.

Finally, it should be expressly remarked that the above, merely arbitrarily selected embodiment serves only to explain the teaching of the invention, without however limiting it to this embodiment.